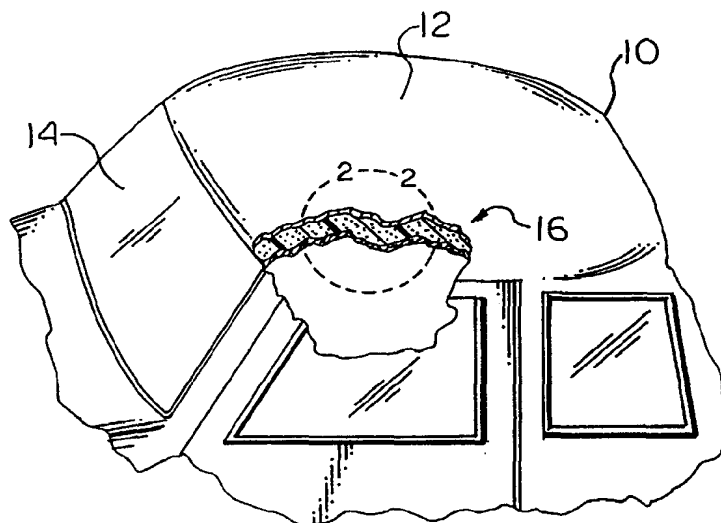




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(54) Title: VEHICLE HEADLINER COMPRISED OF A THERMOFORMABLE THERMOPLASTIC FOAM SHEET

**(57) Abstract**

A vehicle having an improved headliner. The headliner comprises a thermoformed core layer. The core layer comprises an extruded thermoplastic foam and optionally one or more adjacent layers of a substantially non-foamed thermoplastic. The core layer is substantially free of thermoset materials and preferably free of glass or fiberglass mattes or scrim. A decorative layer such a felt layer or a fabric layer is preferably laminated to the core layer. The headliner is substantially resistant to sagging and able to substantially maintain its thermoformed shape when installed in the vehicle. There is also a process for assembling or making a headliner and installing it in a vehicle.

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VEHICLE HEADLINER COMPRISED OF A THERMOFORMABLE THERMOPLASTIC FOAM SHEET

Background of the Invention

The present invention relates to a vehicle headliner having a thermoformed core
5 layer comprised of an extruded thermoplastic foam. The core layer and the headliner are
capable of substantially maintaining their shape and contour when installed in a vehicle
even at elevated temperatures.

Headliners are laminates that are applied to the undersides of roofs of passenger
compartments in vehicles. Headliners serve a variety of purposes, including cushioning,
10 aesthetics, thermal insulation, and sound insulation.

Headliners employed in commercially produced vehicles are relatively complex and
highly engineered due to the physical demands and environmental conditions to which
headliners are exposed. The headliner must have sufficient rigidity to prevent sagging due
to gravity yet be pliable enough to permit fabrication and/or thermoforming and installation.
15 The headliner may also be a component of an overall impact protection system that
provides some degree of cushioning in the event of sudden contact by an occupant in the
passenger compartment. The headliner must also be able to withstand elevated
temperatures associated with exposure of the vehicle to the solar heating. The headliner
must also be able to be formed into a desired shape, configuration, or contour.

Headliners currently employed commercially typically are formed with multiple layers
20 of polyurethane foam and glass/fiberglass mattes or scrim adhered with polyurethane
adhesives and pressed together under heat to a desired shape and contour. Felt or fabric
is typically applied to the headliner at the surface that is to face the interior of the passenger
compartment. Representative headliners include those disclosed in U.S. Patent Nos.
25 5,460,870; 5,486,256; 5,582,906; and 5,670,211, which are incorporated herein by
reference.

The disadvantages of current commercial headliners are many. They are costly due
to expensive component materials and complicated manufacturing methods and processes.
Thermoset adhesives such as polyurethane adhesives are expensive and require multi-
30 step, time-consuming application and curing methods and processes. Reinforcing fabric or
scrim of glass, fiberglass, carbon, or other materials in fibrous form as well as polyurethane
foam sheets must also be interspersed in a layered array along with the thermoset
adhesives. These reinforcing materials are expensive and require multi-step integration into
the manufacturing product along with the thermoset adhesives. Further, the component

materials and the finished headliner product are usually difficult if not impossible to efficiently recycle.

It would be desirable to have a headliner which is comprised of less expensive component materials and which can be assembled by a manufacturing process which is less complex and expensive. It would further be desirable to have a headliner that offers performance features and attributes similar to those afforded by headliners employing thermoset materials and reinforcing fabric or scrim. It would further be desirable if the headliner and/or material components thereof would be readily recyclable.

Summary of the Invention

According to the present invention, there is a vehicle having an improved headliner. The vehicle has a passenger compartment therein and a roof situated overhead of the passenger compartment. The headliner is situated adjacent the underside of the roof. The headliner comprises a thermoformed core layer. The core layer comprises an extruded thermoplastic foam and optionally one or more adjacent layers of a substantially non-foamed thermoplastic. The core layer is substantially free of thermoset materials and preferably free of glass/fiberglass mattes or scrim. The core layer is substantially resistant to sagging and able to substantially maintain its thermoformed shape when the headliner is installed in the vehicle. A decorative layer such a felt layer or a fabric layer is preferably laminated to the core layer.

Further according to the invention, there is a process for assembling or making a headliner and installing it in a vehicle. The process comprises: a) providing a thermoformable core layer comprising an extruded, thermoplastic foam and optionally one or more adjacent layers of a substantially non-foamed thermoplastic wherein the core layer is substantially free of thermoset materials, substantially resistant to sagging, and able to substantially maintain its shape when the headliner is installed in the vehicle; b) thermoforming the core layer by applying heat and mechanical pressure thereto to form the headliner; c) installing or applying the headliner adjacent the underside of the roof. Preferably, a decorative layer is laminated to the surface of the core layer that is to face the interior of the passenger compartment. The decorative layer may be laminated to the core layer either prior to or after the thermoforming of the core layer.

Brief Description of the Drawings

Figure 1 is a fragmentary, perspective view partly in cross-section of a vehicle having a headliner.

Figure 2 is a side view of the cutaway of Figure 1 wherein the roof and headliner of the vehicle are shown.

Figure 3 is a fragmentary, perspective view of a roof of a vehicle having a headliner wherein the headliner is shown in cutaway.

Figure 4 is a fragmentary, perspective view of a roof of a vehicle having a headliner wherein the headliner is shown in cutaway.

5 Figure 5 shows a portion of a headliner having foamed portion and non-foamed portions.

Figures 6-11 illustrate several configurations of a portion of a headliner assembly.

Detailed Description of the Invention

10 The headliner affords many advantages not known in the art with respect to a single headliner. Those advantages are largely related to the thermoformable core layer present in the headliner. Those advantages include the following: the headliner is readily thermoformable to a desired shape, configuration, or contour; the headliner is rigid enough to prevent sagging and substantially maintain its shape - even when exposed to elevated temperatures commonly encountered in vehicles in hot weather and/or direct sunlight
15 conditions; the headliner is preferably comprised of relatively inexpensive and recyclable thermoplastics. The headliner offers good cushioning properties against head bumps and exhibits good sound and thermal absorption.

20 The core layer comprising the thermoplastic foam in the present invention affords significant advantages versus other foam layers taught in the prior art as useful in headliners. U.S. Patent Nos. 5,670,211 discloses headliners having flexible or semirigid foam sheets of polyurethane foam which are processed and formed into a headliner with polyurethane adhesives. The patent also discloses that other foam sheets of PPO, expanded polystyrene, and expanded polypropylene may be substituted for the polyurethane foam. The core layer in the present invention is advantageous over the
25 teachings of the patent in that it is substantially free of thermoset adhesives and can be more easily recycled. The core layer comprising the extruded thermoplastic foam is also more readily thermoformable than polyurethane foam and typically stronger for a given density than expanded (bead) foams, and exhibits higher heat distortion resistance than polystyrene foams. U.S. Patent No. 3,637,458 discloses very thin, extruded polypropylene
30 foam sheets described as useful in a laundry list of applications, including as a headliner. The patent offers no teaching as to the structure of such a headliner or the function that the disclosed polypropylene foam sheet has in it. Foams can serve different functions in a headliner such as to provide structure and mechanical performance or as a cushion backing for a decorative fabric layer. U.S. Patent No. 5,536,793 discloses a polyester foam

described as useful in many applications, including as a headliner. The teachings of this patent are deficient for the same reasons as those of U.S. Patent No. 3,637,458.

The figures depict embodiments of the present invention. In Figure 1, vehicle 10 has a roof 12, a passenger compartment 14, and a headliner 16. Figure 1 shows a cutaway along a circular dotted line 2-2, which corresponds to the cross-sectional side view seen in Figure 2. Figure 2 shows roof 12 having a headliner 16 adhered or affixed thereto. Headliner 16 comprises a conventional extruded thermoplastic foam layer 20, an adhesive layer 22, and a fabric layer 24. Figure 3 shows another embodiment of a roof/headliner combination. In Figure 3, there is a headliner 30 adhered or affixed to a vehicle roof 32. Headliner 30 comprises an extruded, coalesced strand thermoplastic foam 34 and a fabric layer 36. In headliner 30, the strands are oriented generally vertically and generally perpendicular to the plane of roof 32. Figure 4 shows another embodiment of a roof/headliner combination. In Figure 4, there is a headliner 40 adhered or affixed to a vehicle roof 42. Headliner 40 comprises an extruded, coalesced strand thermoplastic foam 44 and a fabric layer 46. In headliner 40, the strands are oriented generally horizontally and generally parallel to the plane of roof 42.

Adhesives known in the art may be employed to adhere various layers of the headliner to each other or the headliner to the roof of the car. Useful adhesives include thermoset adhesives such as polyurethane resins and epoxies and thermoplastic adhesives such as polyethylenes, polypropylenes, ethylene copolymers; propylene copolymers; and the like. Useful adhesives are taught in U.S. Patent Nos. 5,460,870 and 5,670,211. The adhesives may be applied by any means known in the art such as by spraying, coating, or in film form. Preferred adhesives are thermoplastic because of their lower cost and potential recyclability. The presence of an adhesive is not critical to the present invention. The foam may be closed cell or open cell. Open cell content is determined according to ASTM D2856-A. Closed cell foams provide advantages of better thermal insulating capability and resiliency and open cell foams provide advantages of better sound insulation, dimensional stability, and heat transfer during thermoforming.

The thermoplastic foam preferably has a density before thermoforming of from about 16 to about 200 and more preferably from about 16 to about 80 kilograms per cubic meter. The foam has an average cell size of preferably from about 0.1 to about 5.0 and preferably from about 0.2 to about 3.0 millimeters according to ASTM D3576. The indicated foam density and cell size ranges are general in nature for thermoplastic foams. Most preferred density and cell size ranges will vary depending upon the composition of the foam and

desired physical properties. For instance, a foam can usually be made more rigid by increasing density or cell size.

Particularly desirable foams are those of propylene polymers, polyesters, and polyamides having a density before thermoforming of from about 16 to about 160 kilograms per cubic meter and preferably about 24 to about 100 kilograms per cubic meter.

The thermoplastic foam is preferably extruded as a unitary structure but may also be formed by laminating together two or more relatively thinner thermoplastic foam sheets by any means known in the art such as thermal welding or adhesive layers.

The foam must be resistant to heat distortion and be dimensionally stable at elevated temperatures commonly encountered at the roof of a vehicle due to solar heating. The foam preferably exhibits a dimensional stability of about 5 percent or less and more preferably about 1 percent or less with respect to both expansion and shrinkage according to SAE 883.

The foams may be made in any cross-sectional size or configuration such as foam sheet or plank. Particularly useful foams are those having a minor dimension in cross-section (thickness) of 1.5 millimeters or more and preferably 3 millimeters or more.

A layer or layers of a decorative material such a felt or fabric may be applied to the surface of the headliner facing the interior of the passenger compartment or interior cabin for aesthetic appeal. The layer may be of any type known in the art. Those most typically employed commercially are felts or woven fabrics. Useful fabrics include those of woven polyester, nylon, and polypropylene fibers. Preferably, the felt or fabric layer is comprised of the same or similar polymeric material as the foam. The felt or fabric layer may be adhered to the foam by any means known in the art such as thermal welding, adhesive films, or adhesive liquids or coatings. A preferred decorative layer is a woven fabric of thermoplastic fibers thermally welded to the core layer without the benefit of adhesives. Thermal welding refers to the heating of the fabric layer to an extent such that the fibers become tacky or sticky and are able to adhere to the core layer without the benefit of an adhesive. A fabric layer may be thermally welded to a core layer if applied to the core layer during thermoforming or when the core layer is otherwise at an elevated temperature.

A preferred headliner is comprised entirely of recyclable materials. Useful recyclable materials include propylene polymers such as polypropylene; high-density polyethylene; polyesters such as polyethylene terephthalate; and polycarbonates. A most preferred headliner is comprised entirely of recyclable materials of similar composition such that they can be recycled together. For instance, a headliner may comprise any of the following: a laminate of a propylene polymer foam and a woven polypropylene fabric layer; a laminate of

a polyethylene terephthalate foam and a woven polyethylene terephthalate fabric layer; or a polyamide (nylon) foam and a polyamide fabric layer. If desired, different recyclable materials may be employed together such as the following: a) a laminate of a propylene polymer foam and a woven fabric layer of a polyester or a polyamide and b) a laminate of a polyester foam and a woven fabric layer of polypropylene or a polyamide.

The foam is readily thermoformable to a desired shape, configuration, or contour. Typically, the foam and the remainder of the headliner are of substantially the same shape, configuration, or contour as the roof of the vehicle since the headliner is positioned underneath the roof. The term "thermoformable" means the foam may be thermoformed or otherwise shaped under heat and mechanical pressure by any conventional means known in the art to a different shape or contour. Typically, the foam is provided in the form of a substantially flat sheet or plank and pressed under heat and pressure to form a contoured sheet similar in shape and contour to the roof of the vehicle under which it is to be positioned. If desired, a decorative layer such as a fabric layer of woven thermoplastic fibers may be thermally welded to the foam during the thermoforming process.

The physical properties and thermal resistance of the foam may be enhanced by forming or inducing the formation of a substantially non-foamed skin on the foam such as by laminating plastic films or sheets to the foam, by coating it with a plastic resin, heating a surface or surfaces of the foam above its glass transition temperature or the melting point to collapse the cellular structure at the skin, or a combination of any of the foregoing. The film, sheet, or coating may comprise any known thermoplastic resin or thermoset resin. Useful thermoplastic resins include those described above with respect to those composing the foam and useful thermoset resins include polyurethanes and epoxies.

The headliner may be applied to the underside of the roof of the vehicle by any means known in the art such as by adhesion or by affixing by mechanical means. Mechanical means include clips, side molding, and overhead (dome) light assemblies.

Useful thermoplastic foams include but are not limited to those of propylene polymer, polyester, polyamide, polycarbonate, high density polyethylene, chlorinated polyethylene, polyphenylene oxides, blends of polyphenylene oxides and polystyrene, propylene/ethylene copolymers, thermoplastic polyurethanes, blends of EPDM and polyethylene, blends of polypropylene and EPDM, blends of polypropylene and ethylene/styrene copolymers. Ethylene/styrene copolymers and foams containing same are taught in U.S. Patent No. 5,460,818, which is incorporated herein by reference. Preferred foams include propylene polymer foams and polyester foams. More preferred foams

include polypropylene foams, foams of propylene/ethylene copolymers of 95/5 to 99.5/0.5 monomeric weight ratio, and polyethylene terephthalate foams.

A most preferred foam for the core layer is an extruded propylene polymer foam. Suitable propylene polymer materials include propylene homopolymers (polypropylene) and
5 copolymers of propylene and copolymerizable ethylenically unsaturated comonomers. The propylene polymer material may further include non-propylenic polymers. The propylene polymer material may be comprised solely of one or more propylene homopolymers, one or more propylene copolymers, a blend of one or more of each of propylene homopolymers and copolymers, or blends of any of the foregoing with a non-propylenic polymer.

10 Regardless of composition, the propylene polymer material comprises at greater than 50 and preferably about 70 weight percent or more of propylene monomeric units.

Suitable monoethylenically unsaturated comonomers include olefins, vinylacetate, methylacrylate, ethylacrylate, methyl methacrylate, acrylic acid, itaconic acid, maleic acid, maleic anhydride, and the like. The propylene copolymer preferably comprises about 45
15 percent or less by weight of the ethylenically unsaturated comonomer.

Suitable non-propylenic polymers incorporatable in the propylene polymer material include high, medium, low, and linear density polyethylenes, polybutene-1, ethylene/acrylic acid copolymer, ethylene/vinyl acetate copolymer, ethylene/propylene copolymer, styrene/butadiene copolymer, ethylene/styrene copolymer, ethylene/ethyl acrylate
20 copolymer, ionomer and the like.

Particularly useful propylene copolymers are those copolymers of propylene and one or more non-propylenic olefins. Propylene copolymers include random, block, and grafted copolymers of propylene and an olefin selected from the group consisting of ethylene, C₄-C₁₀ 1-olefins, and C₄-C₁₀ dienes. Propylene copolymers also include random terpolymers
25 of propylene and 1-olefins selected from the group consisting of ethylene and C₄-C₈ 1-olefins. In terpolymers having both ethylene and C₄-C₈ 1-olefins, the ethylene content is preferably 45 percent or less by weight. The C₄-C₁₀ 1-olefins include the linear and branched C₄-C₁₀ 1-olefins such as, for example, 1-butene, isobutylene, 1-pentene, 3-methyl-1-butene, 1-hexene, 3,4-dimethyl-1-butene, 1-heptene, 3-methyl-1-hexene, and the
30 like. Examples of C₄-C₁₀ dienes include 1,3-butadiene, 1,4-pentadiene, isoprene, 1,5-hexadiene, 2,3-dimethyl-1,3-hexadiene, and the like.

Also, as used herein, the propylene polymer material has a melt flow rate of between about 0.05 and 50 and preferably between 0.1 and 20 according to ASTM D1238 Condition L.

Preferred propylene polymer resins are those propylene resins that are branched or lightly cross-linked polymer materials. Branching (or light cross-linking) may be obtained by those methods generally known in the art, such as chemical or irradiation branching/light cross-linking. One such resin which is prepared as a branched/lightly cross-linked polypropylene resin prior to using the polypropylene resin to prepare a finished polypropylene resin product and the method of preparing such a polypropylene resin is described in U.S. Patent No. 4,916,198, which is hereby incorporated by reference. Another method to prepare branched/lightly cross-linked polypropylene resin is to introduce chemical compounds into the extruder, along with a polypropylene resin and allow the branching/lightly cross-linking reaction to take place in the extruder. U.S. Patent No. 4,714,716 illustrates this method and is incorporated by reference.

Useful extruded propylene polymer foams are seen in U.S. Patent Nos. 5,348,795; 5,527,573; and 5,567,742, which are incorporated herein by reference.

Useful extruded polyester foams, including polyethylene terephthalate (PET) foams, are seen in U.S. Patent Nos. 5,000,991; 5,234,640; and 5,536,793, which are incorporated herein by reference.

Foams can be made from other useful thermoplastics such as high-density polyethylene, chlorinated polyethylene, TPO mixtures of EPDM rubbers(ethylene/propylene/diamine copolymers)and polyethylene.

Thermoplastic foams useful are preferably non-crosslinked, but may be lightly crosslinked. The term "non-crosslinked" is inclusive however, of the slight degree of crosslinking that occurs naturally without the use of crosslinking agents or radiation. Non-crosslinked foams contain less than 5 percent gel per ASTM D2765-84, Method A. Lightly crosslinked foams contain 5-15 percent gel per ASTM D2765-84, Method A. The blowing agent may comprise any known in the art such as chemical blowing agents and physical blowing agents of organic and/or inorganic composition. Suitable inorganic blowing agents useful include carbon dioxide, nitrogen, argon, water, air, nitrogen, and helium. Suitable organic blowing agents include aliphatic hydrocarbons having 1-9 carbon atoms and halogenated aliphatic hydrocarbons, having 1-4 carbon atoms. Aliphatic hydrocarbons include methane, ethane, propane, n-butane, isobutane, n-pentane, isopentane, neopentane, and the like. Also included are the alcohols such as ethanol, methanol, and propanol. Among halogenated hydrocarbons, fluorinated hydrocarbons are preferred. Examples of fluorinated hydrocarbon include methyl fluoride, perfluoromethane, ethyl fluoride, 1,1-difluoroethane, 1,1,1-trifluoroethane (HFC-143a), 1,1,1,2-tetrafluoroethane (HFC-134a), pentafluoroethane, perfluoroethane, 2,2-difluoropropane, 1,1,1-

trifluoropropane, perfluoropropane, perfluorobutane, perfluorocyclobutane. Partially halogenated chlorocarbons and chlorofluorocarbons for use in this invention include methyl chloride, methylene chloride, ethyl chloride, 1,1,1-trichloroethane, 1,1-dichloro-1-fluoroethane (HCFC-141b), 1-chloro-1,1-difluoroethane (HCFC-142b), 1,1-dichloro-2,2,2-trifluoroethane (HCFC-123) and 1-chloro-1,2,2,2-tetrafluoroethane (HCFC-124). Fully halogenated chlorofluorocarbons include trichloromonofluoromethane (CFC-11), dichlorodifluoromethane (CFC-12), trichlorotrifluoroethane (CFC-113), dichlorotetrafluoroethane (CFC-114), chloroheptafluoropropane, and dichlorohexafluoropropane. Fully halogenated chlorofluorocarbons are not preferred due to their ozone depletion potential. Chemical blowing agents include azodicarbonamide, azodiisobutyro-nitrile, benzenesulfonhydrazide, 4,4-oxybenzene sulfonyl-semicarbazide, p-toluene sulfonyl semi-carbazide, barium azodicarboxylate, N,N'-dimethyl-N,N'-dinitrosoterephthalamide, and trihydrazino triazine

The amount of blowing agent incorporated into the polymer melt to make a foam-forming polymer gel is from about 0.2 to about 4.0, preferably from about 0.3 to about 3.0, and most preferably from about 0.5 to 2.50 moles per kilogram of polymer.

Thermoplastic foams are generally prepared in extrusion processes by heating a thermoplastic to form a plasticized or melt polymer material, incorporating therein a physical blowing agent to form a foamable gel, and extruding the gel through a die to form the foam product. The blowing agent may be incorporated or mixed into the plastic melt by any means known in the art such as with an extruder, mixer, blender, or the like. Prior to mixing with the blowing agent, the plastic material is heated to a temperature at or above the glass transition temperature or the melting point of the plastic material. The blowing agent is mixed with the plastic melt at an elevated pressure sufficient to prevent substantial expansion of the melt and to generally disperse the blowing agent homogeneously within the melt. Optionally, a nucleator is blended in the polymer melt. The feeding rate of blowing agent and nucleator are adjusted to achieve a relatively low density foam and small cell size, which results in a foam having thin cell walls. After incorporation of the blowing agent, the foamable gel is typically cooled to a lower temperature to optimize physical characteristics of the foam product. The gel is then extruded through a die of desired shape to a zone of lower pressure to form the foam product. If a chemical blowing agent is used, it is incorporated into the melt polymer material and extruded or conveyed to a zone of elevated temperature where the agent decomposes to form a gas, usually carbon dioxide. The melt polymer material/gas mixture expands to form a foam.

Other suitable processes for making the thermoplastic foams are the coalesced foam processes described in U.S. Patent Nos. 4,824,720; 5,348,795; 5,527,573; 5,567,742; and WO 88/06094, which are incorporated by reference. These patents relate processes for making open and closed cell polyolefin foams comprising a plurality of coalesced extruded strands or profiles utilizing a die containing a multiplicity of orifices. The orifices are so arranged such that the contact between adjacent streams of the molten extrudate occurs during the foaming process and the contacting surfaces adhere to one another with sufficient adhesion to result in a unitary structure. The individual strands of coalesced foam should remain adhered into a unitary structure to prevent strand delamination under stresses encountered in preparing, shaping, and using the foam.

The extruded, coalesced strand foam affords the advantage of anisotropic physical properties. Such foams exhibit relatively greater compressive strength and impact resistance in the extrusion direction than in the vertical or horizontal directions. When the strands are oriented vertically as in the headliner of Figure 3, greater impact resistance to head bumps is observed for a foam of a given density compared to conventional thermoplastic foams of unitary structure extruded through conventional slit die.

WO 88/06094 relates coalesced strand foam extrusion processes wherein certain orifices within a multi-orifice extrusion die may be blocked or sealed off so that coalesced strand foams having continuous, longitudinal channels of relatively large diameter or dimension can be produced. Coalesced strand foams having such relatively large channels can be employed in the headliner in the manner shown in Figure 4 so that electrical wiring or ducts for vented, cooled, or heated air may be channeled from the front of the passenger compartment to the rear or back of that compartment if desired.

U.S. Patent No. 4,323,528, herein incorporated by reference, relates making polyolefin foams via an accumulating extrusion process. The process comprises: 1) mixing a thermoplastic material and a blowing agent to form a polymer gel; 2) extruding the gel into a holding zone maintained at a temperature and pressure which does not allow the mixture to foam; the holding zone has a die defining an orifice opening into a zone of lower pressure at which the gel foams and an openable gate closing the die orifice; 3) periodically opening the gate; 4) substantially concurrently applying mechanical pressure by means of a movable ram on the gel to eject it from the holding zone through the die orifice into the zone of lower pressure, and 5) allowing the ejected gel to expand to form the foam.

Foam strength may be enhanced by incorporating relatively thin substantially non-foamed plates or profiles into the foam portion of the headliner. This may be accomplished by any suitable method, such as by extruding the desired plate/profile and foam

combination directly by using extrudates or plastic melts with and without blowing agent, which are conveyed through different orifices within the extrusion die and allowed to coalesce to form a plate/profile and foam combination having both foamed and non-foamed resin portions. Another method is to extrude the foam under conditions such that it contacts
5 the plates or profile upon extrusion, thereby forming the desired combination. In the extrusion cross-section of the foam, the non-foamed resin plates or portions can take on a regular or irregular pattern. The plates or profiles may be intersecting or non-intersecting with respect to each other. Possible cross-section patterns for non-foamed profiles or plates within the foam include honeycomb-shaped, circular, rectangular or diagonal grid
10 patterns. Figure 5 shows a plate/profile and foam combination having a rectangular grid pattern that has foamed portions 51 and non-foamed portions 52.

It is also possible to manufacture extruded structures having foamed and non-foamed portions by cutting a foam with a hot wire and subsequently reuniting or coalescing the severed foam pieces so that they are heat welded together. Preferably, heat welding
15 would occur immediately after the foam has been severed by the hot wire. The application of heat to the foam collapses the cellular structure of the foam adjacent the wire and creates a non-foamed plate or profile within the foam after severed foam pieces are coalesced.

20 It is also possible to manufacture structures having foamed and non-foamed portions by laminating foamed and non-foamed profiles or layers to each other in an alternating configuration to form a unitary structure. Such profiles or layers could be laminated together by heat welding or adhesion.

In addition, a nucleating agent may be added in the foaming process in order to
25 control the size of foam cells. Preferred nucleating agents include inorganic substances such as calcium carbonate, talc, clay, titanium dioxide, silica, barium sulfate, calcium stearate, barium stearate, diatomaceous earth, mixtures of citric acid and sodium bicarbonate, and the like. The amount of nucleating agent employed may range from about 0.01 to about 5 parts by weight per hundred parts by weight of a polymer resin. The
30 preferred range is from 0.1 to about 3 parts by weight.

It is also possible to add various additives in the foam and in the foaming process such as pigments, antioxidants, acid scavengers, ultraviolet absorbers, flame retardants, processing aids, extrusion aids, and the like.

The physical properties and thermal resistance of the foam may be enhanced by
35 adding particulates or fibers of organic or inorganic materials in the form of fillers. Such

particulates or fibers could be added to foam-forming compositions during manufacturing. Useful materials include carbon black particulates, clay particulates, carbon or graphite fibers, polypropylene fibers, polyester fibers, and nylon fibers, glass fibers, and acrylonitrile fibers. The physical properties and thermal resistance of the foam may also be enhanced
5 by laminating to the foam non-foamed film/sheet layers or coatings containing such particulates and/or fibers. Fibers may be of any length, short (fibrils) or long. They may be randomly dispersed or woven or placed together in the nature of a fabric or prepreg.

Adhesives known in the art may be employed to adhere various layers of the headliner to each other or the headliner to the roof of the car. Useful adhesives include
10 thermoset adhesives such as polyurethane resins and epoxies and thermoplastic adhesives such as polyethylenes, polypropylenes, ethylene copolymers; propylene copolymers; and the like. Useful adhesives are taught in U.S. Patent Nos. 5,460,870 and 5,670,211. The adhesives may be applied by any means known in the art such as by spraying, coating, or in film form. Preferred adhesives are thermoplastic because of their lower cost and
15 potential recyclability. The presence of an adhesive is not critical to the present invention.

A layer or layers of a decorative material such a felt or fabric may be applied to the surface of the headliner facing the interior of the passenger compartment or interior cabin for aesthetic appeal. The layer may be of any type known in the art. Those most typically employed commercially are felts or woven fabrics. Useful fabrics include those of woven
20 polyester, nylon, and polypropylene fibers. Preferably, the felt or fabric layer is comprised of the same or similar polymeric material as the foam. The felt or fabric layer may be adhered to the foam by any means known in the art such as thermal welding, adhesive films, or adhesive liquids or coatings. A preferred decorative layer is a woven fabric of thermoplastic fibers thermally welded to the core layer without the benefit of adhesives.
25 Thermal welding refers to the heating of the fabric layer to an extent such that the fibers become tacky or sticky and are able to adhere to the core layer without the benefit of an adhesive. A fabric layer may also be thermally welded to a core layer if applied to the core layer during thermoforming or when the core layer is at an elevated temperature.

A preferred headliner is comprised entirely of recyclable materials. Useful recyclable
30 materials include propylene polymers such as polypropylene; high-density polyethylene; polyesters such as polyethylene terephthalate; and polycarbonates. A most preferred headliner is comprised entirely of recyclable materials of similar composition such that they can be recycled together. For instance, a headliner may comprise any of the following: a laminate of a propylene polymer foam and a woven polypropylene fabric layer; a laminate of
35 a polyethylene terephthalate foam and a woven polyethylene terephthalate fabric layer; or a

polyamide (nylon) foam and a polyamide fabric layer. If desired, different recyclable materials may be employed together such as the following: a) a laminate of a propylene polymer foam and a woven fabric layer of a polyester or a polyamide and b) a laminate of a polyester foam and a woven fabric layer of polypropylene or a polyamide.

5 The foam is readily thermoformable to a desired shape, configuration, or contour. Typically, the foam and the remainder of the headliner are of substantially the same shape, configuration, or contour as the roof of the vehicle since the headliner is positioned underneath the roof. The term "thermoformable" means the foam may be thermoformed or otherwise shaped under heat and mechanical pressure by any means known in the art to a
10 different shape or contour. Typically, the foam is provided in the form of a substantially flat sheet or plank and pressed under heat and pressure to form a contoured sheet similar in shape and contour to the roof of the vehicle under which it is to be positioned. If desired, a decorative layer such as a fabric layer of woven thermoplastic fibers may be thermally welded to the foam during the thermoforming process.

15 The physical properties and thermal resistance of the foam may be enhanced by forming or inducing the formation of a substantially non-foamed skin on the foam such as by laminating plastic films or sheets to the foam, by coating it with a plastic resin, heating a surface or surfaces of the foam below its glass transition temperature or the melting point to collapse the cellular structure at the skin, or a combination of any of the foregoing. The
20 film, sheet, or coating may comprise any known thermoplastic resin or thermoset resin. Useful thermoplastic resins include those described above with respect to those composing the foam and useful thermoset resins include polyurethanes and epoxies.

 The headliner may be applied to the underside of the roof of the vehicle by any means known in the art such as by adhesion or by affixing by mechanical means.

25 Mechanical means include clips, side molding, and overhead light assembly.

 The term "vehicle" is inclusive of those known in the art such as automobiles, trucks, recreational vehicles, sport utility vehicles, airplanes, trains, and boats.

 Figures 6-10 illustrate portions of several different headliner configurations. Fig. 6 shows two foams sheets 61 and 62 comprised of foam strands having a vertical
30 orientation, a foam-backed fabric sheet 63 and layers of adhesive film 64 and 65. In a preferred embodiment, the headliner contains the second foam sheet 62 only at certain locations on the headliner where additional energy absorption capability is desired, such as along the sides of the headliner nearest the passenger doors, but elsewhere is comprised of a single foam sheet in order to minimize the thickness of the headliner at such other
35 locations. Adhesive film layers 64 and 65 may be used to adhere the fabric and foam

layers 66 and 67 and to enhance the overall stiffness of the headliner. If desired, the film layers may be omitted and the fabric and foam layers adhered to each other by any other suitable means, such as by hot-welding the foams layers together and using a liquid fabric adhesive to the foam layer adjacent thereto.

5 Figures 7-9 show several ways in which two layers of foam may be oriented within the headliner. The top foam layers 71, 81, and 91 in these configurations are comprised of strand foams which is positioned so the strands are perpendicular with respect to the roof of the vehicle, so that the maximum energy absorption is achieved. The bottom foam layer is shown as a strand foam layer 72 having strands perpendicular to the roof, a
10 non-strand foam 82, and strand foam which is positioned so the strands are perpendicular with respect to the roof of the vehicle 92. In these embodiment, the layers of foam may be attached to each other by suitable means, such as by using adhesives, adhesive films, or by hot-welding them together.

 Figure 10 shows a portion of the headliner foam as a single piece of strand
15 foam which has been cut or molded to the desired shape, having thinner portions and thicker portions, the thicker portions being located along the side of the headliner nearest the passenger side doors. Figure 11 shows a portions of a headliner having three layers of strand foam, 96, 97, and 98, the third layer providing extra energy absorption capability.

EXAMPLES

20 Foams that could be thermoformed and fabricated to form headliners suitable for installation into vehicles were prepared in the examples below.

Example 1

 An extruded polypropylene foam sheet was produced.

 The apparatus for producing the foam comprised an extruder, mixer, cooler, and an
25 annular extrusion die in series. The polymer was fed in granular form to the extruder where it was mixed with additives to form a polymer melt. The polymer melt was conveyed to the mixer where a blowing agent was incorporated therein under pressure to form a foamable gel. The foamable gel was conveyed to the die where it expanded out of the annular orifice around a mandrel to form a tubular foam sheet product. The tubular sheet was then split to
30 form a flat sheet.

 The propylene polymer resin was 98/2 polypropylene (homopolymer) resin [Montell HMS resin PF-814]. The blowing agent was 8 pph isobutane (parts per hundred based upon polymer weight). Additives employed were 0.2 pph talc (nucleating agent), 0.1 pph Irganox 1010 (antioxidant), and 0.1 pph Ultrinox 626 (antioxidant).

The foam had a thickness of 5 millimeters (mm) and a width of 1600 mm, an open cell content of 1.6 percent, a density of 2.7 pounds per cubic foot (pcf) (43.2 kilograms per cubic meter (kgm)) and an average cell size of 1.7 mm. The foam had a Foamability Index value as described by in US Patent 5,527,573 of 5.3. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 2

Another extruded polypropylene foam sheet was produced on the apparatus disclosed in Example 1 with the same blowing agent content and loading and substantially the same processing conditions as in Example 1 but with a larger die gap opening and a slower take-away draw speed.

The foam had a thickness of 9 mm and a width of 1600 mm wide, an open cell content less than 2 percent, a density of 2.41 pcf (38 kgm), and an average cell size 1.7 mm. The foam had a Foamability Index value as described by in US Patent 5,527,573 of 4.7. The foam was relatively rigid and did not sag when supporting its own weight. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 3

Another extruded propylene copolymer foam sheet was produced on the apparatus disclosed in Example 1 with the same blowing agent content and loading and substantially the same processing conditions as in Example 1.

The foam had a thickness of 7 mm and a width of 1600 mm wide, an open cell content 19 percent, and a density of 2.9 pcf (46.1 kgm) and an average cell size of 1.75 mm. The foam had a Foamability Index value as described by in US Patent 5,527,573 of 5.8. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 4

An extruded polypropylene foam sheet was produced on the apparatus disclosed in Example 1 with the same blowing agent and additives plus the addition of calcium stearate

powder for additional cell nucleation. The polypropylene polymer was fed to the extruder at 990 lb/h (449 kg/h), along with 0.42 pph talc, 0.3 pph Ultrinox™ 815P stabilizer (from GE Specialty Chemicals), 0.3 pph calcium stearate. The plasticized gel mixture was then mixed with 3.9 pph isobutane under pressure, cooled to 161°C and conveyed to an annular die where it was allowed to expand into a region of lower pressure, stretched over a 16" diameter cooling mandrel to form a tubular foam sheet product. The tubular sheet was then split to form a flat sheet.

The foam had a thickness of 7 mm and a width of 1290 mm, an open cell content of 20.4%, a density of 3.3 pcf (52.9 kgm) and an average cell size of 3.6 mm. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam had a flexural strength at failure value of 175 psi (1.21 MPa) as tested by the method described in SAE J949, and a Foamability Factor of 13.6. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 5

Another extruded polypropylene foam sheet was produced on the apparatus disclosed in Example 1 with the same blowing agent and additives plus the addition of calcium stearate powder for additional cell nucleation. The polypropylene polymer was fed to the extruder at 1380 lb/h (626 kg/h), along with 0.30 pph talc, 0.21 pph Ultrinox™ 815P stabilizer (from GE Specialty Chemicals), 0.3 pph calcium stearate. The plasticized gel mixture was then mixed with 3.9 pph isobutane under pressure, cooled to 161.5°C and conveyed to an annular die where it was allowed to expand into a region of lower pressure, stretched over a 20 inch diameter cooling mandrel to form a tubular foam sheet product. The tubular sheet was then split to form a flat sheet.

The foam had a thickness of 10.9 mm and a width of 1600 mm, an open cell content of 2.2%, a density of 3.4 pcf (54.5 kgm) and an average cell size of 5.2 mm. The foam was relatively rigid, did not sag when supporting its own weight, and thermoformable. The foam had a flexural strength at failure value of 141 psi (1 MPa) as tested by the method described in SAE J949, a Foamability Factor of 20.3. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 6

An extruded foam sheet was produced from a blend of 75% polypropylene PF-814 from Montell and 25% AFFINITY™ PL-1880 polyethylene from The Dow Chemical Company. PL-1880 is polyethylene resin with a 1.0 dg/min melt index value with a 0.9020 g/cc density and a I10/I2 of 9.0. The foam sheet was made on the apparatus disclosed in Example 1. The polymer blend was fed to the extruder at 1000 lb/h (454 kg/h), along with 0.4 pph talc and 0.3 pph Ultranox™ 815P stabilizer (from GE Specialty Chemicals). The plasticized gel mixture was then mixed with 6.0 pph isobutane under pressure, cooled to 157°C and conveyed to an annular die where it was allowed to expand into a region of lower pressure, stretched over a 20 inch diameter cooling mandrel to form a tubular foam sheet product. The tubular sheet was then split to form a flat sheet.

The foam had a thickness of 7 mm and a width of 1600 mm, an open cell content of 14.4%, a density of 3.6 pcf (57.7 kgm) and an average cell size of 3.4 mm. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam had a flexural strength at failure value of 72 psi (0.5 MPa) as tested by the method described in SAE J949, and a Foamability Factor of 14.0. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 7

An extruded foam sheet was produced from a blend of 75% polypropylene PF-814 from Montell and 25% AFFINITY™ PL-1880 polyethylene from The Dow Chemical Company. PL-1880 is polyethylene resin with a 1.0 dg/min melt index value with a 0.9020 g/cc density and a I10/I2 of 9.0. The foam sheet was made on the apparatus disclosed in Example 1. The polymer blend was fed to the extruder at 1000 lb/h (454 kg/h), along with 0.4 pph talc and 0.3 pph Ultranox™ 815P stabilizer (from GE Specialty Chemicals). The plasticized gel mixture was then mixed with 6.0 pph isobutane under pressure, cooled to 157°C and conveyed to an annular die where it was allowed to expand into a region of lower pressure, stretched over a 20 inch diameter cooling mandrel to form a tubular foam sheet product. The tubular sheet was then split to form a flat sheet.

The foam had a thickness of 9.8 mm and a width of 1600 mm, an open cell content of 5.8%, a density of 2.7 pcf (43.3 kgm) and an average cell size of 4.5 mm. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam had a flexural strength at failure value of 70 psi (0.5 MPa) as tested by the method described in SAE J949, and a Foamability Factor of 13.0. The foam was cut and molded

into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 8

5 An extruded foam sheet was produced from a blend of 75% polypropylene PF-814 from Montell and 25% AFFINITY™ PL-1880 polyethylene from The Dow Chemical Company. PL-1880 is polyethylene resin with a 1.0 dg/min melt index value with a 0.9020 g/cc density and a I10/I2 of 9.0. The foam sheet was made on the apparatus disclosed in Example 1. The polymer blend was fed to the extruder at 1200 lb/h (545 kg/h), along with
10 0.4 pph talc and 0.3 pph Ultranox™ 815P stabilizer (from GE Specialty Chemicals). The plasticized gel mixture was then mixed with 6.0 pph isobutane under pressure, cooled to 156°C and conveyed to an annular die where it was allowed to expand into a region of lower pressure, stretched over a 20 inch diameter cooling mandrel to form a tubular foam sheet product. The tubular sheet was then split to form a flat sheet.

15 The foam had a thickness of 14.6 mm and a width of 1600 mm, an open cell content of 3.3%, a density of 2.6 pcf (41.7 kgm) and an average cell size of 3.2 mm. The foam was relatively rigid, did not sag when supporting its own weight, and was thermoformable. The foam had a flexural strength at failure value of 58 psi (0.4 MPa) as tested by the method described in SAE J949. The foam has a Foamability Factor of 9.5. The foam was cut and
20 molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 9

 The foam sheet of Example 8 was laminated with a 1.6 mil (0.04 mm) thick
25 multilayer film. The film was made of two layers: a) ethylene acrylic acid copolymer / linear low density polyethylene blend (60/40); b) homopolymer polypropylene. The adhesive layer a) composed XX% of the thickness of the film. The film was laminated to one side of the foam. After the lamination, the film/foam structure was cut into a 3 inch by 12 inch section and tested for flex strength, as in SAE Test J949. The resultant structure required greater
30 than 25 newtons to bend 1 inch (25.4 mm). The foam has a Foamability Factor of 9.5. The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 10

The foam sheet of Example 5 was laminated with a 1.6 mil (0.04 mm) thick multilayer film as described in Example 9. The film was laminated to one side of the foam. After the lamination, the film/foam structure was cut into a 3 inch by 12-inch section and
5 tested for flex strength, as in SAE Test J949. The foam has a Foamability Factor of 20.3. The resultant structure required greater than 45 newtons to bend 1 inch (25.4 mm). The foam of Example 5 required 20 newtons to bend the foam 1 inch (25.4 mm). The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the
10 underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

Example 11

The foam sheet of Example 7 was laminated with a 1.6 mil (0.04 mm) thick multilayer film as described in Example 9. The film was laminated to one side of the foam. After the lamination, the film/foam structure was cut into a 3 inch by 12 inch section and
15 tested for flex strength, as in SAE Test J949. The foam has a Foamability Factor of 13.0. The resultant structure required greater than 14 newtons to bend 1 inch (25.4 mm). The foam was cut and molded into the desired profile of a vehicle headliner, and a layer of a decorative fabric was adhered thereto. The headliner was installed in a vehicle adjacent to the underside of the vehicle roof, and attached thereto by means of a suitable adhesive.

20

CLAIMS:

1. A vehicle, the vehicle having a passenger compartment and a roof situated overhead of the passenger compartment, the vehicle having a headliner situated adjacent the underside of the roof, the headliner comprising a thermoformed core layer, the core
5 layer comprising an extruded thermoplastic foam and optionally one or more adjacent layers of a substantially non-foamed thermoplastic, the core layer being substantially free of thermoset materials, the core layer being substantially resistant to sagging and able to substantially maintain its shape.
2. The vehicle of Claim 1, wherein the core layer has laminated to one of its major
10 surfaces a decorative layer.
3. The vehicle of Claim 2, wherein the decorative layer is selected from the group consisting of a felt layer and a fabric layer.
4. The vehicle of Claim 1, wherein the core layer is substantially free of mattes of fibers of thermoset or thermoplastic materials.
- 15 5. The vehicle of Claim 1, wherein the core layer consists essentially of an extruded thermoplastic foam, the headliner further having a decorative layer laminated to a major surface of the core layer.
6. The vehicle of Claim 1, wherein the core layer consists essentially of an extruded thermoplastic foam and one or more layers of a substantially non-foamed thermoplastic.
- 20 7. The vehicle of Claim 1, wherein the foam has a density of about 16 to about 160 kilograms per cubic meter prior to fabrication or thermoforming.
8. The vehicle of Claim 1, wherein the foam has a density of about 16 to about 80 kilograms per cubic meter prior to fabrication or thermoforming.
9. The vehicle of Claim 1, wherein the thermoplastic comprises greater than 50
25 weight percent of propylene monomeric units based upon the total weight of the propylene polymer material.
10. The vehicle of Claim 1, wherein the thermoplastic comprises about 70 weight percent or more of propylene monomeric units based upon the total weight of the propylene polymer material.
- 30 11. The vehicle of Claim 1, wherein the foam is a polyester foam.
12. The vehicle of Claim 1, wherein the foam is a polycarbonate.
13. The vehicle of Claim 1, wherein the foam is a polyamide.
14. The vehicle of Claim 1, wherein the foam has a cross-sectional thickness of 1.5 millimeters or more.

15. The vehicle of Claim 1, wherein the foam has a cross-sectional thickness of 3 millimeters or more.

16. The vehicle of Claim 1, wherein the foam is made up of two or more laminated sheets.

5 17. The vehicle of Claim 9, wherein the foam is an extruded foam of coalesced strand configuration.

18. The vehicle of Claim 1, wherein the foam has a filler in the form of a particulate and/or fiber.

10 19. The vehicle of Claim 1, wherein the foam has a cross-sectional thickness of 1.5 millimeters or more, the thermoplastic comprises greater than 50 weight percent of propylene monomeric units based upon the total weight of the propylene polymer material, the foam having a density of about 16 to about 160 kilograms per cubic meter prior to fabrication or thermoforming.

15 20. The vehicle of Claim 1, wherein the foam has a cross-sectional thickness of 3 millimeters or more, the thermoplastic comprises about 70 weight percent or more of propylene monomeric units based upon the total weight of the propylene polymer material, the foam having a density of about 16 to about 80 kilograms per cubic meter prior to fabrication or thermoforming.

20 21. The vehicle of Claim 1, wherein the foam has one or more non-foamed plates or profiles therein.

22. A process for assembling a headliner and installing it in a vehicle, the vehicle having a passenger compartment and a roof situated overhead of the passenger compartment, the process comprising: a) providing a thermoformable core layer comprising an extruded, thermoplastic foam and optionally one or more adjacent layers of a
25 substantially non-foamed thermoplastic wherein the core layer is substantially free of thermoset materials, substantially resistant to sagging, and able to substantially maintain its shape; b) thermoforming the core layer by applying heat and mechanical pressure thereto to form the headliner; c) positioning the headliner adjacent the underside of the roof.

23. The process of Claim 22, wherein a decorative layer is placed adjacent
30 and parallel to the core layer and laminated thereto, the decorative layer being laminated to the core layer either prior to or after thermoforming the core layer.

24. The process of Claim 22, wherein the foam has a cross-sectional thickness of 1.5 millimeters or more, the thermoplastic comprises greater than 50 weight percent of propylene monomeric units based upon the total weight of the propylene polymer

material, the foam having a density of about 16 to about 160 kilograms per cubic meter prior to fabrication or thermoforming.

25. The process of Claim 22, wherein the foam has a cross-sectional thickness of 3 millimeters or more, the thermoplastic comprises about 70 weight percent or
5 more of propylene monomeric units based upon the total weight of the propylene polymer material, the foam having a density of about 16 to about 80 kilograms per cubic meter prior to fabrication or thermoforming.

26. The process of Claim 22, wherein the foam has one or more non-foamed plates or profiles therein.

10 27. The process of Claim 22, wherein the foam is a polyester foam.

28. The process of Claim 22, wherein the foam is a polycarbonate foam.

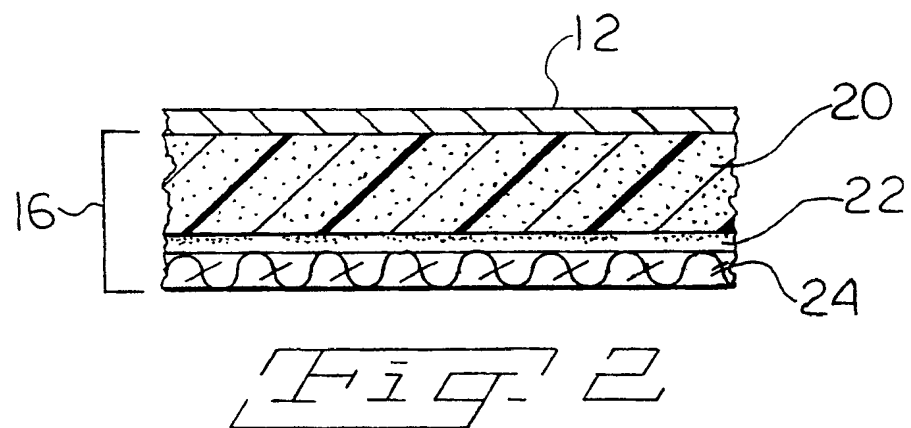
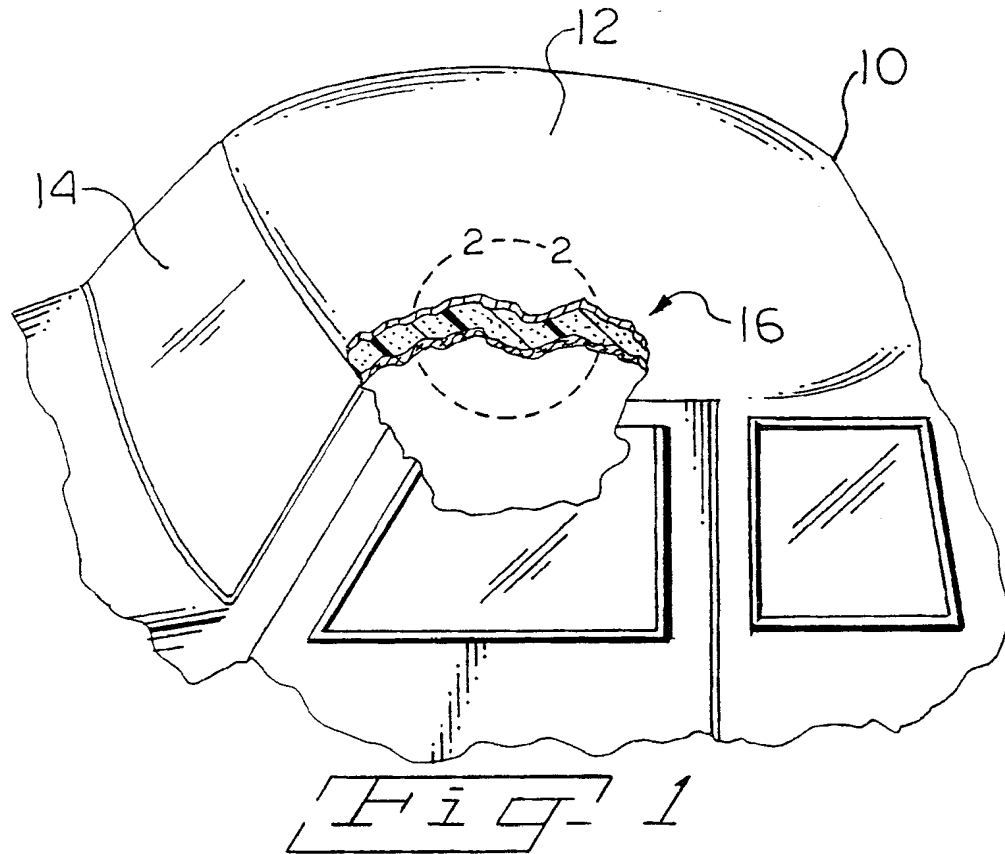
29. The process of Claim 22, wherein the foam is a polyamide foam.

30. The process of Claim 1, wherein the foam has one or more non-foamed plates or profiles therein.

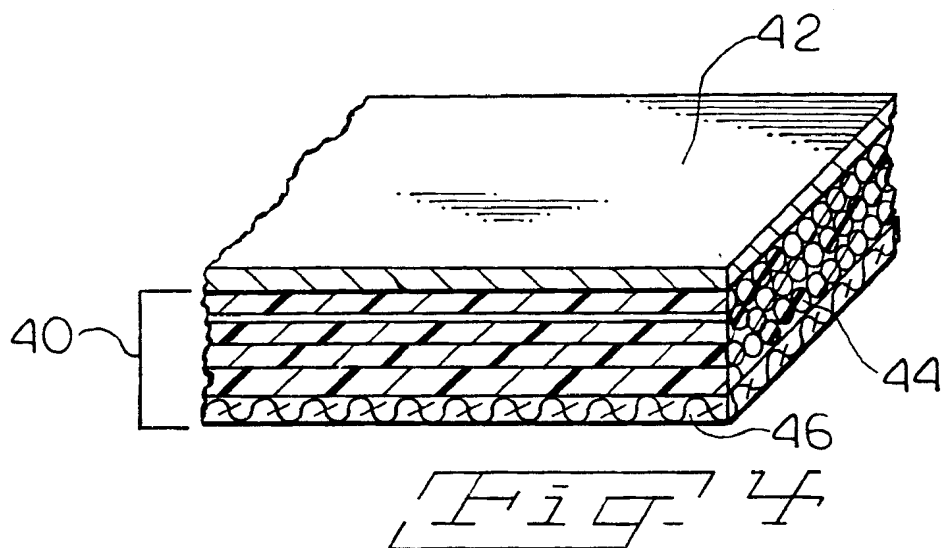
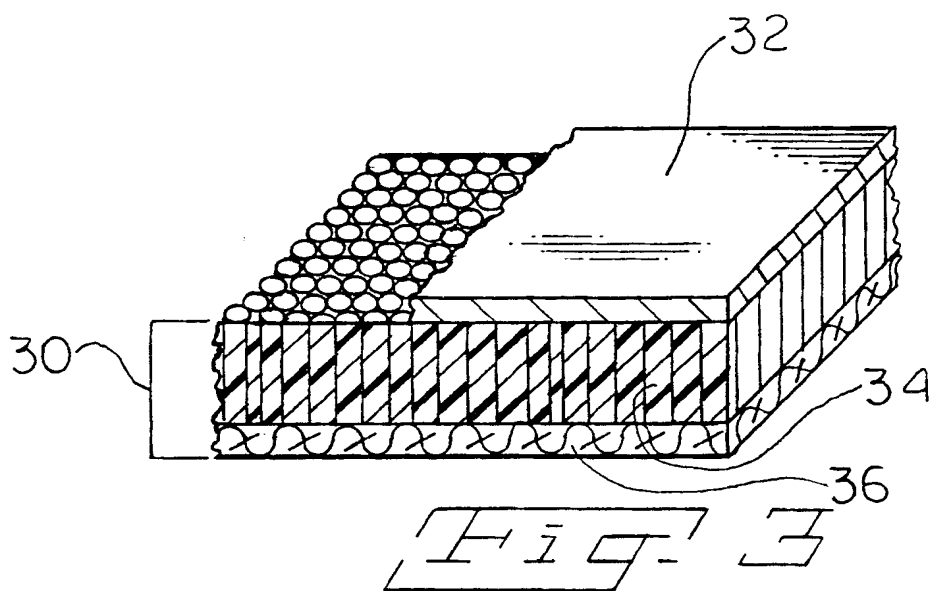
15 31. A vehicle headliner having at least one thermoformed core layer having a thickness in the range of from 1.5 mm to 25 mm, the core layer consisting of an extruded thermoplastic foam having a gel content of less than 10 percent and, before thermoforming, an open cell content of less than 50 percent, a density in the range of from 16 to 200 kilograms per cubic meter, a width of at least 12 inches, and an average cell size in the
20 range of from 1.0 to 5.5 mm.

32. The headliner of claim 30 wherein the thermoplastic foam has a foamability index of greater than 2.0.

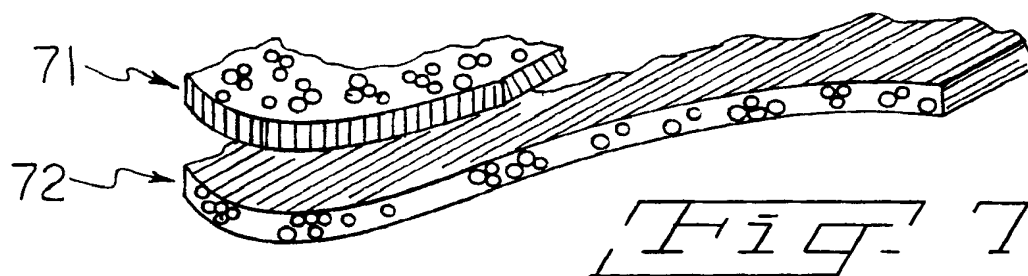
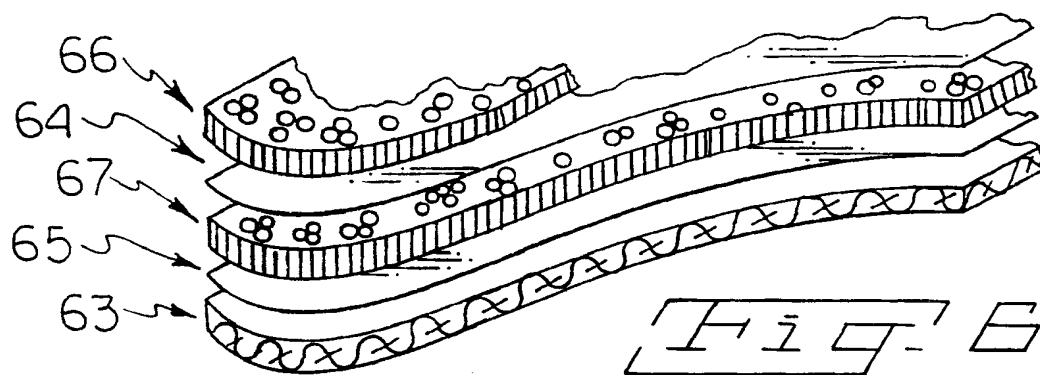
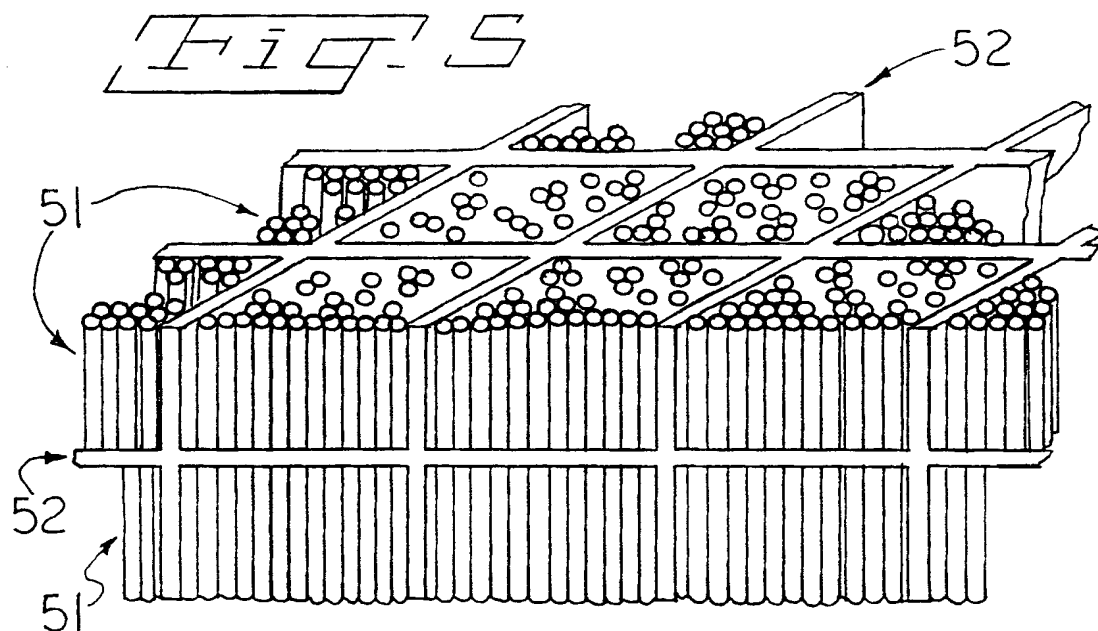
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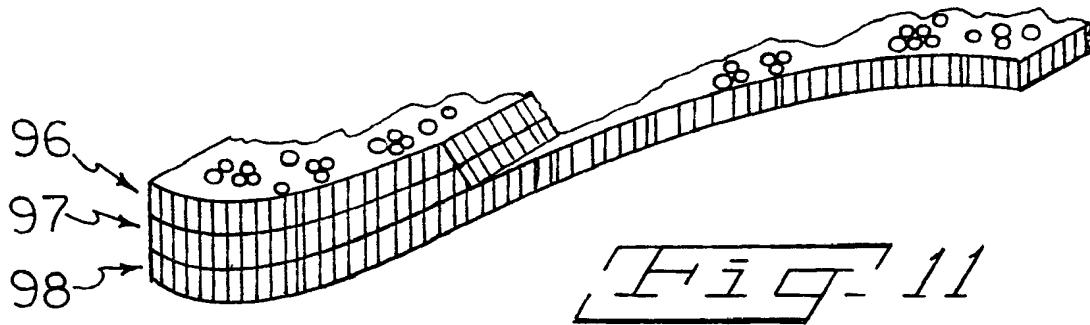
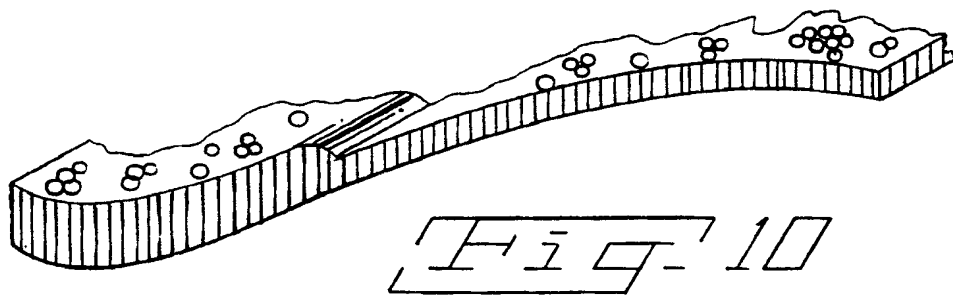
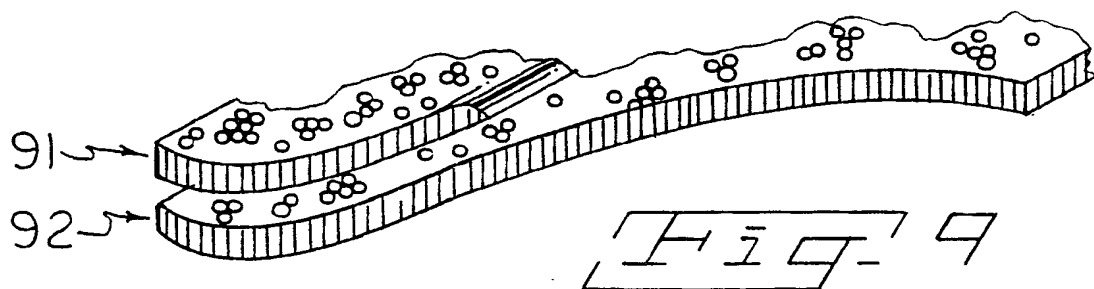
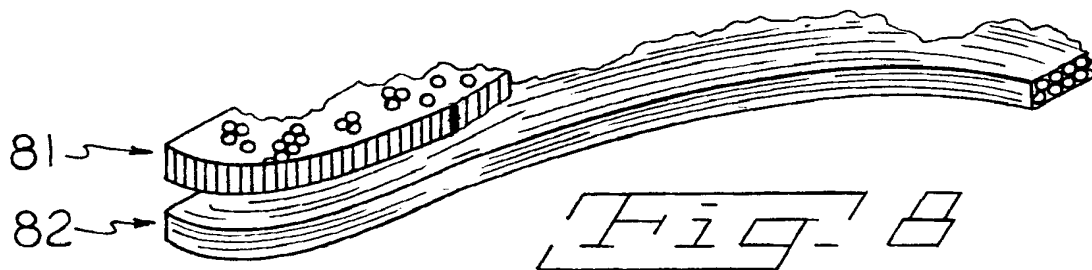


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INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/US 99/09304

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 B60R13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 330 584 A (R.P. DOERER) 18 May 1982 (1982-05-18) see column 1, line 11- line 17; column 2, line 12 - line 46; column 3, line 34 - column, line 23 figures 1-3	1-8, 14-16, 21-23, 31, 32
Y	US 4 128 683 A (T. NOMURA) 5 December 1978 (1978-12-05) the whole document	1-8, 14-16, 21-23, 31, 32
A	EP 0 419 439 A (MONSANTO COMPANY) 27 March 1991 (1991-03-27) page 3, line 19-24	1, 11, 13, 27, 29
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/US 99/09304

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